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DYNAMIC BEHAVIOUR OF COASTAL SEDIMENTATION  
IN THE LIONS GULF

Max GUY

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JUL 30 1974

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(Final report)

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<p>15. Abstract : A number of ERTS-1 images covering this geographical zone were studied and compared with cartographic maps, air photographs and thermal-IR images. <u>Old and recent sediments</u>. They leave traces in the landscape which are decoded by interpreting the shapes of the clear zones forming a network against the black background representing water and humid zones (MSS bands 6 and 7).</p> <p>Field work is currently being conducted to study the corresponding sedimentary models.</p> <p><u>Current sedimentation and its mechanism</u>. It had been hoped that a regular sequence of images would make it possible to follow the dynamics of the Rhone and the coastal rivers in relation to meteorological conditions. In the event only a small number of images spread over a wide period of time were obtained, and a complete study was therefore impossible. However, the comparison of ERTS images, certain thermal-IR images and information on the flow of the Rhone provided some clarification of mechanisms, associated with river dynamics.</p> <p>It was planned to do a correlation between meteorological events (rain or dry weather) upon river basins of homogeneous ecological conditions, river flow and river mouth plumes at sea. Unfortunately the lack of closely repeated coverage lead to resume this part of the project : the ecological study only was done by C.E.P.E. of Montpellier.</p>		

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O - PREFACE

O.1.- OBJECTIVES OF THE PROJECT GOLION

1) Using image repetition to point out mechanisms of sedimentation. For example, to see whether various coastal currents or coastal river effluents can be examined.

2) Determining whether very small-scale images can be used to plot general sedimentation mechanisms that are difficult to synthesize from data gathered on a large scale, either on the ground or by airphotos.

O.2.- SCOPE OF ACTIVITY (until APRIL 74)

Due to clouds and haze, very few images useful for this project have been available until MARCH 19<sup>th</sup>73 (image of JAN.26.73)

On MARCH 21<sup>th</sup>73, another good image was obtained and thermographic surveys were planned for JUNE-JULY 73 and obtained on JUNE 24<sup>th</sup> and JULY 6<sup>th</sup>73 (I G N-CNES flights), but ERTS image were not taken in this period. Presently, the investigation of sedimentological process is beginning because the technical problems are in the way of being solved.

The study of the remains of the holocene beaches has been conducted without major difficulties and a general study of these remains in the delta was published in MARCH 73 at the 2<sup>nd</sup>ERTS Symposium.

O.3.- SIGNIFICANT FINDINGS

O.3.1.- Present sedimentological processes

The images taken on JAN 26<sup>th</sup> 73 and MARCH 21<sup>th</sup>73 show a light toned strip along the coast. Study of meteorological data does not allow to attribute these strip to the waters of the Rhone. But they can be linked to the accumulation of sand and dust carried by the wind. On the 26 January 1973 image as well as on the 21 September 1973 Skylab photo we also found that these light strips, in addition to running parallel to the coast, outlined protuberances running offshore. This suggested return currents (rip currents) entraining surface water.

A thermographic mission carried out on June 73 on a very small scale (1/100,000 th) showed that this hypothesis was quite probable.

O.3.2.- Historical outline of the Rhone Delta

The interpretation tends to prove the existence of three successive morphological structures of the Rhone Delta. Two extreme phases can clearly be seen. Initial phase was a vast triangular delta and the present image is of an elongated delta. Intermediate stages appear to have existed between these two extreme phases and a detailed map is currently checked in the field.

O.4.- CONCLUSIONS

This survey has shown that satellite images may be of considerable help in guiding a survey of recent sedimentation in a delta, by providing an overall interpretation pattern.

Whereas the weather did not enable as much advantage as had been hoped to be taken of the image repetition, the coinciding of some images with specific meteorological circumstances enabled hypotheses to be put forward. The combined use of airborne thermography was also tested. Likewise, it was found that it was almost impossible in practice to synchronized plane flights with satellite passages.

In this sense, the experiments have entirely fulfilled their purpose which was to try out a new operating method. Material difficulties appeared and seriously compromised or at least considerably delayed the project. However, the results are promising, and new approaches were found.

## 1 - OBJECTIVES OF THE PROJECT GOLION

The Golion project in the Gulf of Lions, proposed to NASA by the Institut Français du Pétrole and several co-investigators (1), had the following dual objective :

- i. Determining whether very small-scale images can be used to plot general sedimentation mechanisms that are difficult to synthesize from data gathered on a large scale, either on the ground or by airphotos.
- ii. Using image repetition to point out such mechanisms from a kinematic and dynamic standpoint. For example, to see whether various coastal currents or coastal river effluents can be examined. At the same time, to see whether meteorological disturbances spotted in river basins as the result of changes in the surface vegetation appearance of effluents, etc.

## 2 - SUMMARY OF THE ACCOMPLISHMENTS DURING THE PERIOD JULY 1, 1972 TO MARCH 31, 1974

### 2.1 - Data receipt

ID NUMBER	DATE	RECEIVED	LOCALISATION
1058-09450	09.09.72	10.25.72	NICE - CORSE
1060-09561	09.21.72	11.17.72	East Rhone
1061-10015	09.22.72	11.08.72	West Rhone
1061-10022	09.22.72	11.08.72	DELTA RHONE - BEZIERS
1076-09442	10.07.72	11.23.72	MILAN PO
1076-09445	10.07.72	11.23.72	GENES PO - TURIN
1076-09451	10.07.72	11.23.72	NICE - CORSE
1078-09562	10.09.72	11.23.72	EAST RHONE
1078-09564	10.09.72	11.23.72	RHONE DELTA
1149-09511	12.19.72	02.06.73	TURIN - NICE
1150-09565	12.20.72	02.06.73	VALENCE-AVIGNON-GRENOBLE
1150-09572	12.20.72	02.06.73	MARSEILLE-RHONE DELTA
1166-09454	01.05.73	02.06.73	NICE - LE VAR
1167-09512	01.26.73	02.06.73	TOULON - NICE
1187-10023	01.26.73	03.19.73	VALENCE - LE PUY - AVIGNON
1187-10025	01.26.73	03.19.73	NARBONNE-BEZIERS
1187-10032	01.26.73	03.19.73	PYRENEES - COTE ESPAGNOLE
1204-09573	02.12.73	04.04.73	MARSEILLE - RHONE DELTA
1221-09513	03.01.73	04.05.73	TURIN - MEDITERRANEE
1221-09515	03.01.73	04.05.73	TOULON - NICE
1222-09571	03.02.73	04.05.73	VALENCE - AVIGNON - GRENOBLE
1241-10033	03.21.73	06.01.73	DELTA RHONE - BEZIERS

### 2.2 - Scope of activity (MARCH 73 - APRIL 74)

It will be noted that very few images useful for this project have been available until JAN 26th 73 (received MARCH 19th) this image shows the first case of sea water differentiation along the coast as expected in the project.

Due to clouds and haze the image of 09.22.72, 10.09.72, 12.20.72, were of a very poor help.

.../...





	D A T E	CUMULATE WIND ENERGY						OUTFLON of the RHONE (m3/sec.)	HAZE  CLOUDS	COMMENTS  ON 4 and 5 MSS bands	
		PERPIGNAN			MARSEILLE						
		3 d.	6 d.	9 d.	3 d.	6 d.	9 d.				
E1								600	3 7	INUSABLE IMAGE - TOO CLOUDY	O
E1		W 15	ESE 25	ESE 50	E 5	E 15	E 40	500	5 1	HAZE - THE LIGHT GREY STRIP NOT SEEN ALONG THE COAST; TROUBLESOME HAZE	E
E1								1,200	1 4	ABUNDANT CLOUDS	E
E1		NNW 35	NNW 150	NNW180	E 10	NNW 90	NW 90	1,200	1 2	LIGHT GREY TONED, CURRENT SHAPED STRIP ALONG THE COAST.	O
E1		NW 75	NW 80	NW 110	NW 105	NW 105	NW 110	1,000	2 2	SUCH A STRIP BEGINS IN THE WESTERN ZONE (RHONE DELTA)	E
E1								1,200		image not received	O
E1		ESE 5	SE 5	NW 95	NW 30	NW 55	NW 105	800	2 1	LIGHT GREY STRIP FUZZIER THAN ON JANV. 26	

WIND : Cumulate wind energy during 3 days, 6 days, 6 days, or 9 days preceding image taking at PERPIGNAN and MARSEILLE. The period of higher energy is underlined, except when the mean wind was slight variable.

CLOUDS : The upper left figure indicates haze and dispersed clouds in tenth of the image area while bottom right figure indicates the tenth of dense.

On MARCH 21<sup>th</sup>73, another good image was obtained, but the white toned band was not present along the coast like on the JAN 26<sup>th</sup> image. At this time, thermographic surveys were planned for JUNE-JULY 73 and obtained on JUNE 24<sup>th</sup> and JULY 6<sup>th</sup>73 (I G N-C N E S flights), but ERTS images were not taken in this period.

The lack of repetition of the images in the beginning of the study has lead to change the ways planned for this investigation : after the first type I report (DEC.72) the investigation of the present mechanism of was suspended until JUNE 73, when a trial was done by CNES to have a thermographic surveys to map the longshore currents partially seen on ERTS images.

Another problem has been the bad quality of MSS band 4 and 5 images, whose negatives were very light toned. A precise mapping of the "like current strips on enlargements was very difficult. Recently (APRIL 73) we have got digital tapes, through "TRONU" project, and the mapping is currently done by mean of computer.

At this time, the investigation of sedimentological process is really beginning because these technical problems are in the way of being solved. Moreover we have the good fortune of obtaining (through "PYRALP" project) three SKYLAB-EREP photographs that gave very good shows of the phenomenon in the gulf and at the mouth of Rhône.

The study of the remains of the holocene beaches has been conducted without major difficulties, but the field control demands many time, labo analysis (radiocarbon dating....) that are planned for two or three years since JULY 73.

### 2.3 - Major problems and conclusions -

As indicated above, whereas the first part of this project was carried out "as per forecast" and even better than expected, the second part produced only fragmentary although highly instructive results. There are technical reasons for this, such as partial repetition due mainly to bad weather. At the same time there are reasons stemming from the material organization of the collaboration. For example, image enlargements were not regularly transmitted because the volume handled by the photography laboratory had been planned for normal exposure time whereas the images received required a very long time and numerous tests. Actually, several prints had to be made of each image so as to bring out contrast between land, water, clouds, etc... However, the aim of the ERTS 1 experiment was not necessarily to obtain scientific results but rather to learn how to handle these images which we made the mistake of tending to consider as not being very different from airphotos.

Bearing this in mind, we can go on to say that the results already acquired are quite interesting, and we can affirm that a great deal of new knowledge will certainly be gained from analyzing these images in the years to come.

.../...

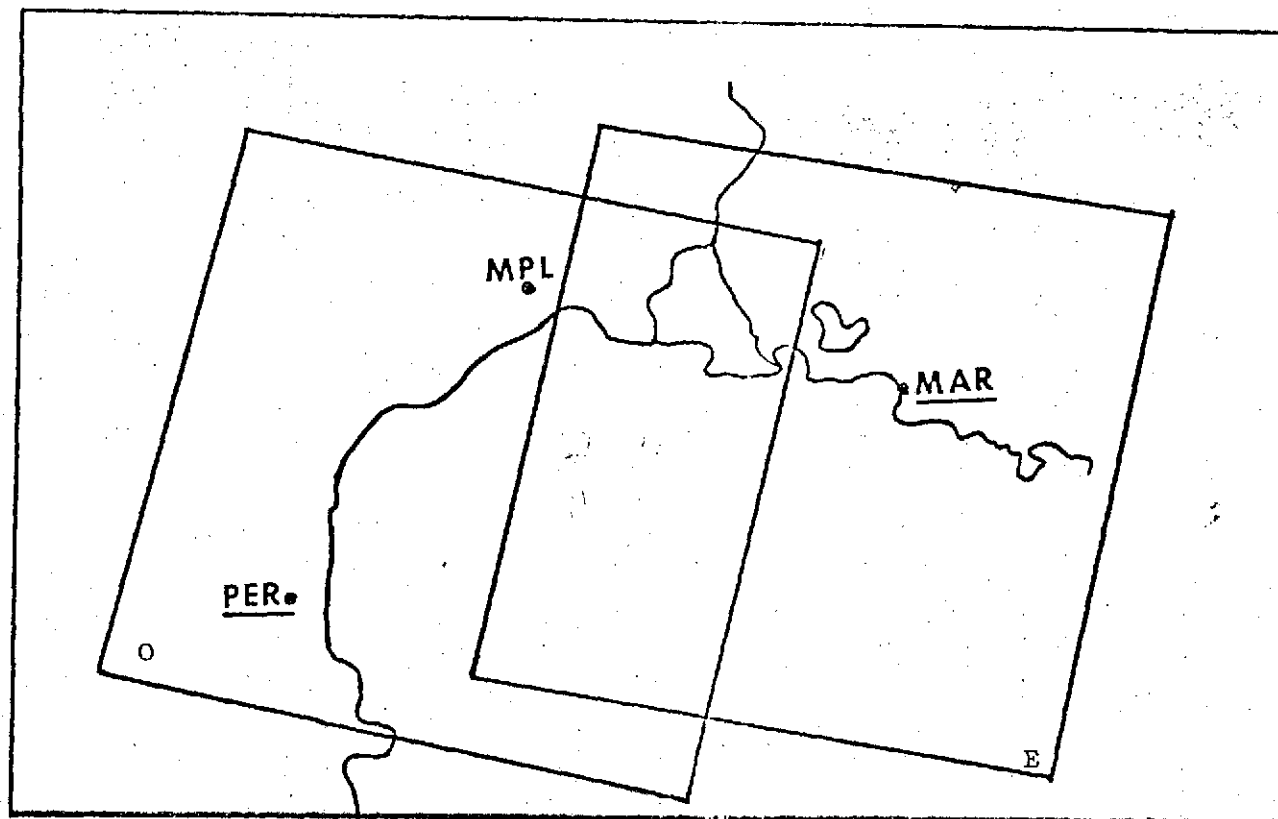
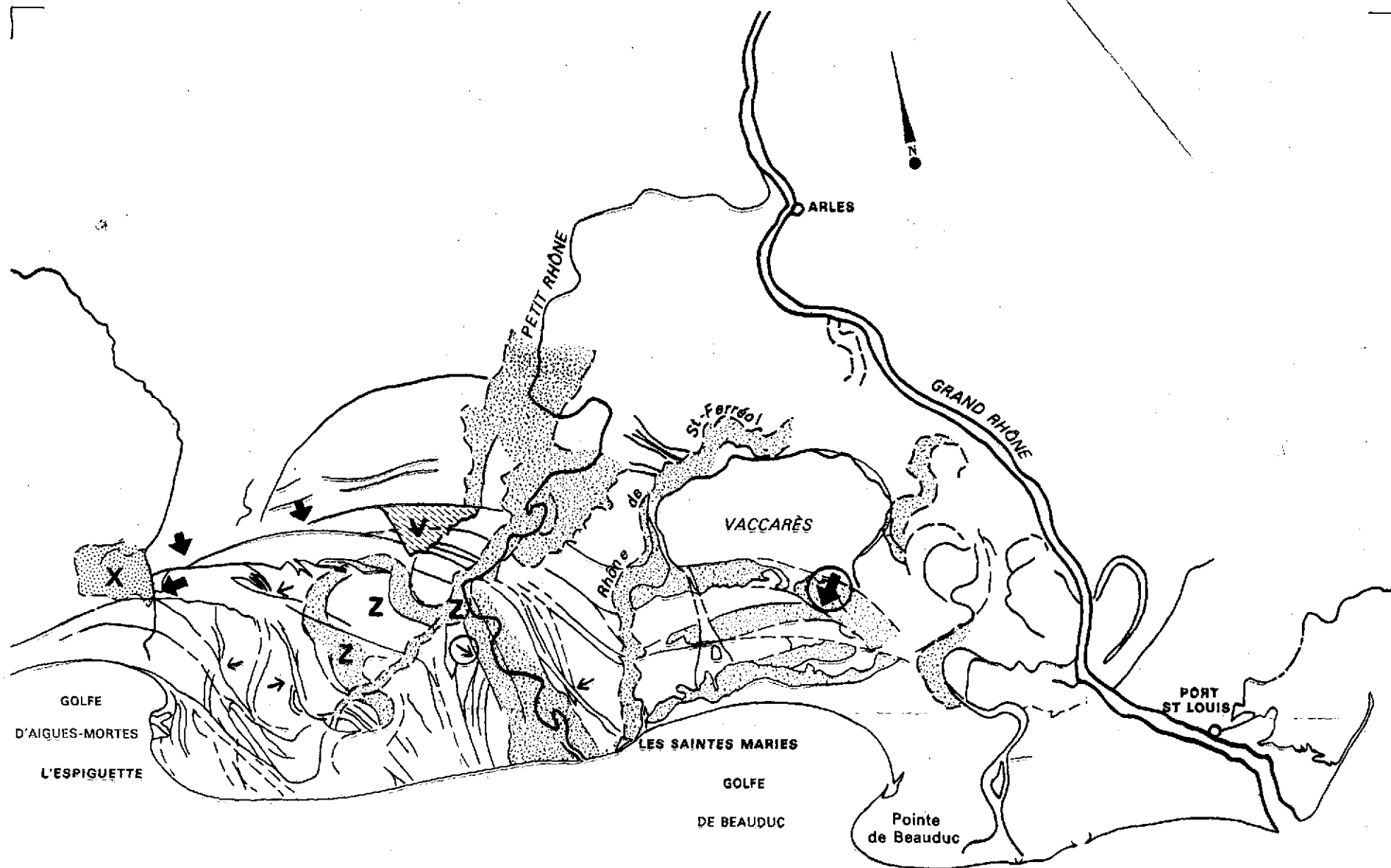





Fig. 1 : Position of images in table 3 (O = West, E = East) Main meteorological stations are underlined.



 Côte et cours actuels des bras du Rhône  
 Tracés méandriformes : levées alluviales (claires), anciens cours (sombres).

 Tracés en forme de rivages (dessin net - dessin flou).  
**XVZZ** Voir texte



5 4 3 8 3 6 0 0 0 4

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photo NASA - ERTS 1 - USA

F FRANCE

NASA ERTS 1 - MSS 6  
cliché ID n° 1078-09 564

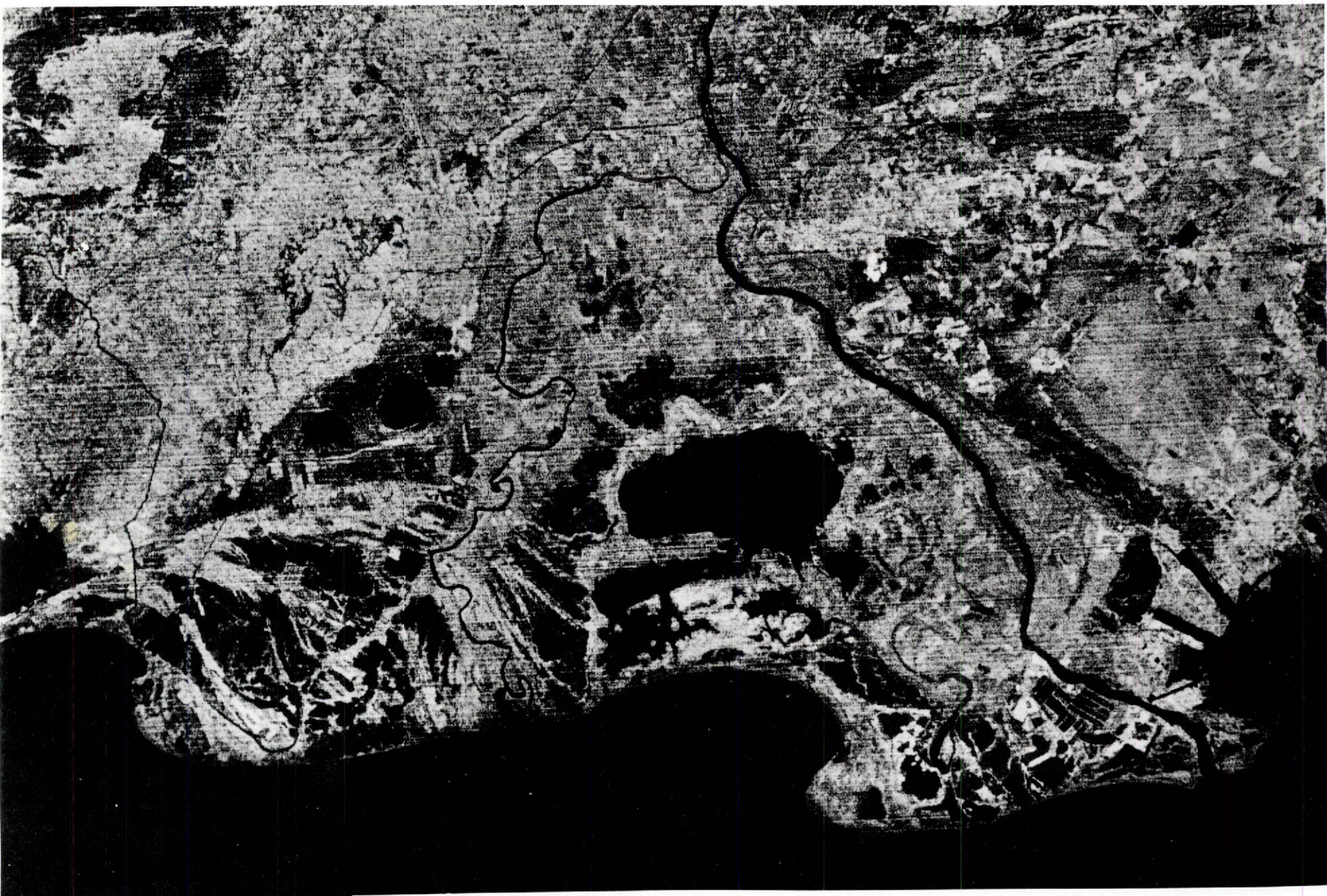
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73-1  
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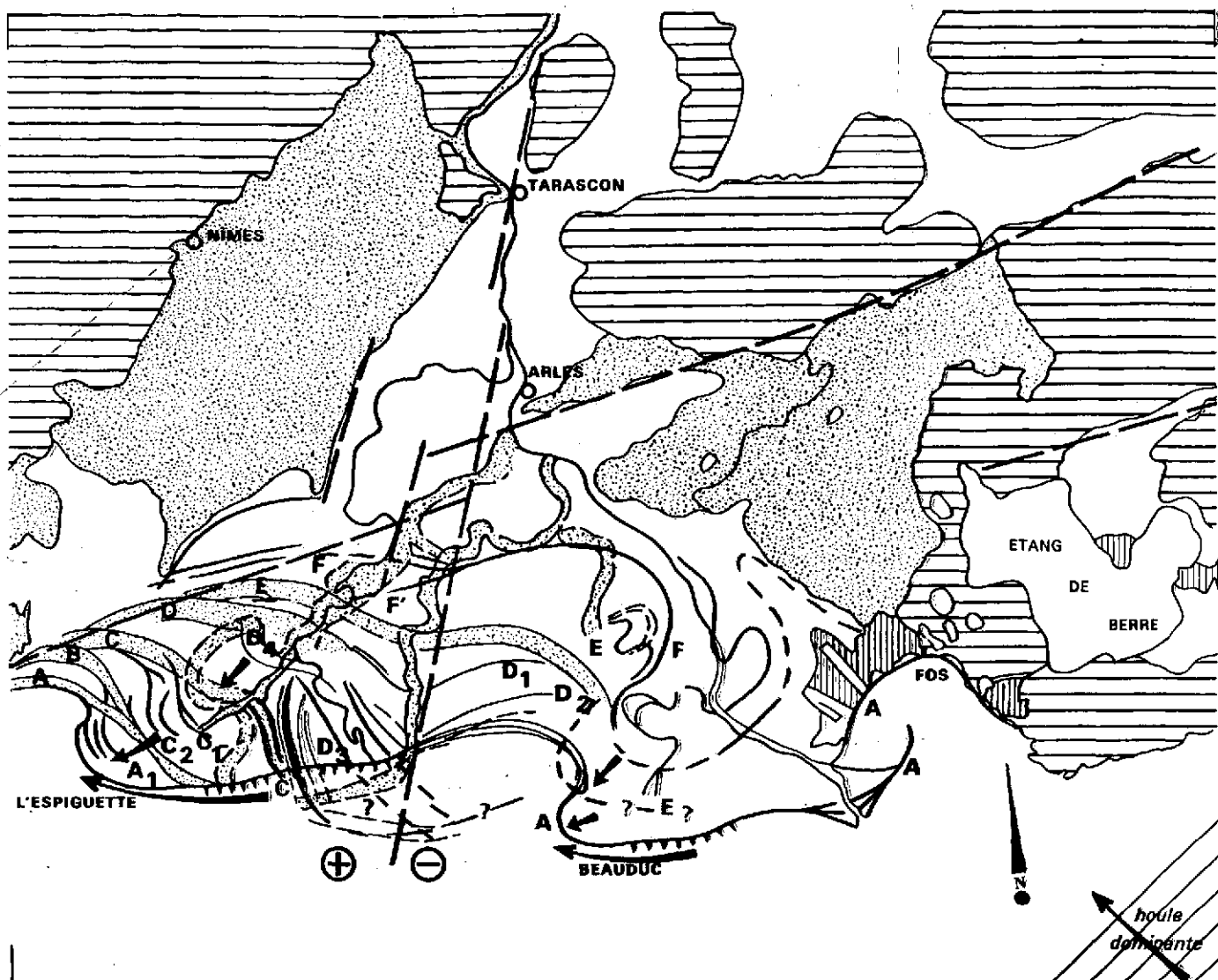
4 0 0 0 6 3 8 4 5



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73-1  
6-7-1





- |  |  |
|--|--|
|  | Anté-quaternaire                               |
|  | Pléistocène                                    |
|  | Terrains artificiels                           |
|  | Alignements morphologiques (failles possibles) |
|  | Flèches d'embouchure                           |
|  | Anciens méandres                               |
|  | Levées alluviales                              |
|  | Cordons littoraux                              |
|  | Pointe en construction                         |
|  | Côte en érosion                                |
|  | Direction de transport                         |
|  | Compartiment stable ou élevé-abaisse.          |

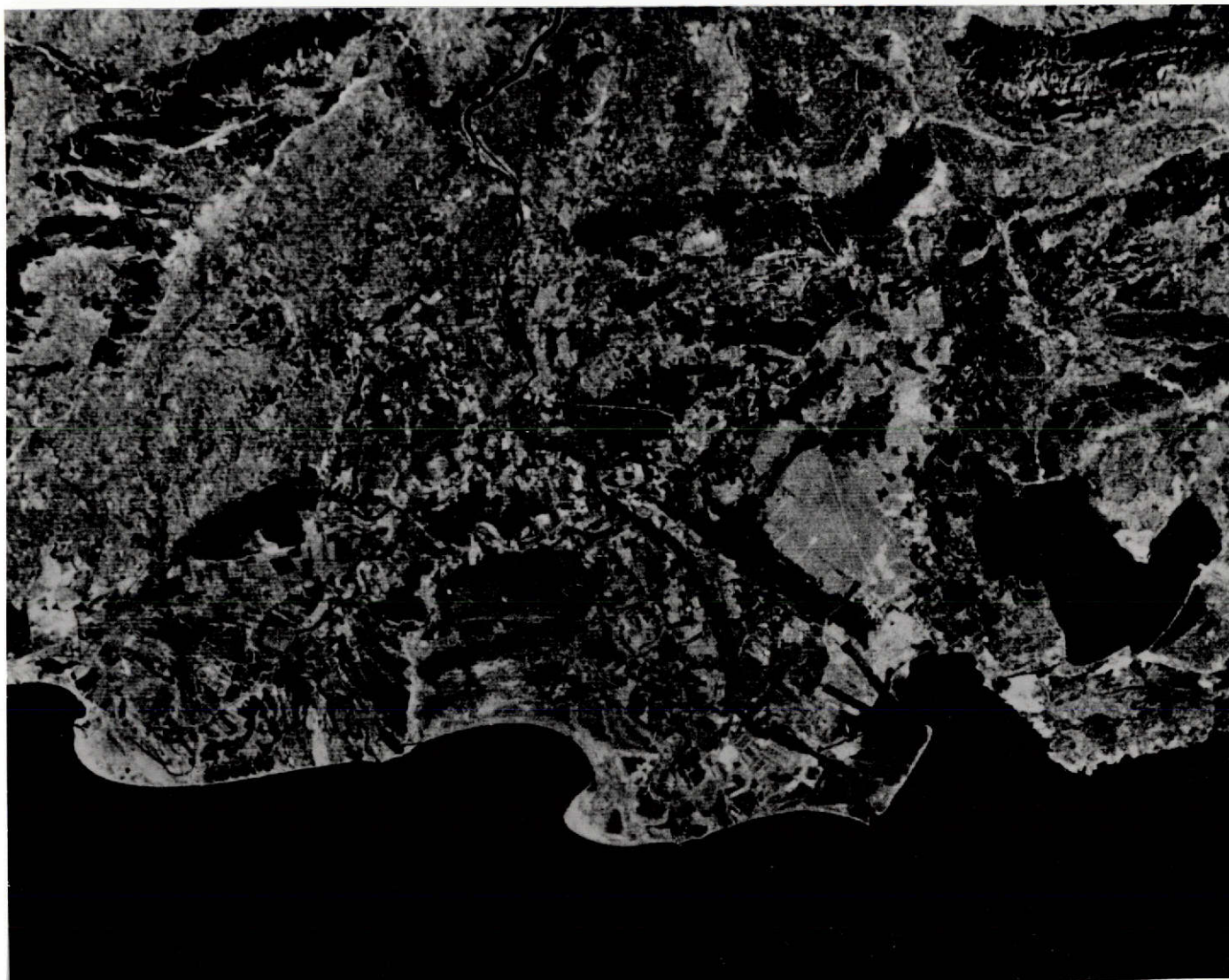


photo NASA - ERTS 1 - USA

F FRANCE	NASA-ERTS 1-MSS 5 cliché ID n° 1078-09 564	9-10-72 10 h 56	1 : 500 000 0,6-0,7 $\mu$	1 : 100 000 F feuille ARLES N-22
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	1	2	3	4	5	6	7	8	9		
7	ANTE-PRIMAIRE PRIMAIRE	SECONDAIRE	TERTIAIRE	QUATERNAIRE PALEOLITHIQUE	NEOLITHIQUE PROTHISTOIRE	500	500	1000	1500	TEMPS MODERNES	4
0		COLONISATION	HABITAT RURAL		FORTIFICATIONS GUERRES	HABITAT URBAIN		LOISIRS LIEUX PUBLICS	RELIGIONS NECROPOLES	0	
0	EXPLOITATION SOUS-SOL	PRODUCTION D'ENERGIE	INDUSTRIE TRANSFORMATION	INDUSTRIE CONSUMMATION	DISTRIBUTION		COMMUNICATIONS AERIENNES	COMMUNICATIONS MARITIMES	COMMUNICATIONS TERRESTRES	0	
0	COUVERT VEGETAL	EXPLOITATION DIRECTE DE LA VEGETATION	ORIENTATION ALIGNEMENTS	AMENAGEMENT IRRIGATION DRAINAGE CONSERVATION	GENIE RURAL REMEMBREMENT	STRUCTURES AGRAIRES	EXPLOITATION AGRICOLE		MONDE ANIMAL ELEVAGE CHASSE PECHE	0	
6	LIGNES	POLYGONES CARRÉS	CERCLES RAYONS	METHODES EMULSIONS	REPARTITION CARTOGRAPHIE	SATELLITE	ETUDE DYNAMIQUE EVOLUTION	DEGRADATION		6	
3	RESEAU HYDROGRAPHIQUE	VERSANTS	MICRORELIEF		DOCUMENTS ANCIENS	FORMATIONS SUPERFICIELLES	SOLS BRUTS NON DU PEU EVOLUES	SOLS EVOLUES		3	
8	RELIEF NUL	RELIEF FAIBLE	RELIEF FORT				VENTS	Eaux	NEIGES ET GLACES	8	
4	ARCTIQUE SUB-ARCTIQUE	TEMPERE CONTINENTAL	TEMPERE OCEANIQUE	MEDITERRANEEN	PREDESERTIQUE	DESERTIQUE ARIDE	INTERTROPICAL	EQUATORIAL TRES HUMIDE	MICROCLIMATS	4	
5	CRISTALLIN	EFFUSIF FILOIEN	METAMORPHIQUE	SEDIMENTAIRE STRATIGRAPHIQUE	MERS Eaux SALES	STRUCTURES QUASI MONOCLINALES	STRUCTURES PLUSSEES	STRUCTURES FAILLEES	STRUCTURES POLYGENES DISCORDANCES	5	

73-1  
6-7-8

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### 3 - SIGNIFICANT RESULTS

The results already acquired are presented in two parts, one corresponding to a "static" or "historic" survey describing the shapes inherited from the Holocene delta and used to propose interpretation models, and the other summing up attempts to make a dynamic interpretation of the situation spotted on the images, with regard to both the difficulties encountered and the results obtained.

#### 3.1 - Data on the historical survey of the Rhone delta

The Rhone delta is the same type of large-size sedimentary structure (a = 2500 sq km) that was difficult to encompass as a whole before the advent of satellite images taken at very high altitudes.

An initial exploitation of ERTS documents by photointerpretation showed the coexistence of simple coastal morphological features, present dynamic reflections and more complex fixed features giving evidence of previous delta construction stages. A series of hypotheses was then put forward, but various obscure points still remain.

A program of field checks and sediment analyses was then undertaken, while the photographic documents were re-examined in detail with the help of sedimentologists. Attention was mainly focused on present and fossilized coastal structure. These are the initial achievements of this second phase as described here.

##### 3.1.1 - Data provided by photointerpretation

The ERTS 1 satellite images provided an overall and relatively detailed view of the entire Rhone delta, so that coherent links could be made between traces of former bars or alluvial levees that appear discontinuously on the airphotos.

For quite a long time, geologists had spotted in the field and linked together on maps at least two very old offshore coastal bars, and they had noted the historical shorelines according to medieval texts as well as to 18th century old maps. However, all this remained rather hazy because there was no way of being accurate about the geometry of the vestiges as a whole.

The images describes (fig.2 and 3) were taken on 9 October 1972 in the spectral bands of the MSS 5 multispectral scanner (0.6 to 0.7 ) and the MSS 6 multispectral scanner (0.7 to 0.8 ).

The image in band MSS 4 was not used because it was too fuzzy as the result of a veil caused by atmospheric haze. Images 6 and 7 taken in the infrared can be used with a great deal of fineness to separate the dry land and submerged zones, hence to bring out the filigrain pattern of all the microrelief in the Camargue Plain. The image in band 5 (red) provides a great deal of contrast in showing the differences in vegetation and shallow lagoon bottoms.

An enlargement to a scale of approximately 1 : 300,000 th of image MSS 6 (fig.2) brings out as objective an outline as possible of the slight clear-colored reliefs of the bars or levees.

.../...



### Outline of Traces According to the Image in Spectral Band 6 (fig.2)

The present beds of the Large and Small Rhone can be seen in black. In the eastern part of the image, near the Large Rhone, former meander-shaped beds can be seen by their darker color. In the central and western part, lighter-colored meander-shaped outlines must be identified with the alluvial levees of former beds that are now only very occasionally perceptible (SW bank at Vaccarès).

West of the coast, an extraordinary light-hued pony tail begins on top of the dark sea-bottom. This feature is made of fine and light-colored lines. A detailed analysis of the system shows at least two types of shapes, i.e. fairly-large inverted S-shaped light-colored bars, followed by less-obvious parallel incurved lines that are almost concentric and follow the outline of the coast at the point of Espiguette or Beauduc. A certain number of graphic unconformities can be seen between the outline of the main bars (indicated by heavy-print arrows on the overlay) or between the fine shapes (slender arrows). In other places, the shapes intersect and appear to pass underneath one another.

This image also shows that, E of the former levee called the Saint-Ferreol Rhone, the prolongation of the bar outline gets thicker as if it were being buried underneath more recent fill. Even farther E, the bar pattern can no longer be seen, but according to his pattern, we are behind the oldest bar in the network which stands out clearly.

In addition, we can see that the shape of the coast at the Vaccarès pond and the dark plain to the NW is similar to that of the Gulf of Beauduc or Aigues-Mortes. This would appear to indicate a system of coastal gulfs that had already been installed and was then cut across by the first bar in the pattern we are now investigating.

In some cases, it is not easy to discern whether a trace belongs to a bar network or an alluvial levee. For example, a rounded shape shown in green on the overlay may appear as a headland of the Espiguette type or as part of a meander pattern that has been indicated by red Zs.

Likewise, as at X, a very recent alluvial fan may sometimes cover part of the former traces or, as at Z, a patch of dune sand may mask their outline.

Such ambiguities could be removed by making a field study of the nature of the deposits.

But the structure as a whole thus determined raises the difficult problem of the mechanism and causes of its evolution. Several factors can be mentioned such as variations in the inflow of delta material via the river or in the method of coastal transport, eustatic variations in the sealevel, the subsidence or uplifting of various geological compartments, etc.... Since such factors are not independent of the another, it is difficult to isolate them as a general rule. Nonetheless, a comparison of existing shapes, for which the mechanism can be determined, and former shapes, or else the fact that favorable circumstances reveal the preponderant influence of any one parameter, may help clarify the issue.

.../...

.../...

### 3.1.2 - Attempt to Make a Genetic Interpretation of the Sand Bars

The procedure used for photointerpretation consisted in characterizing the present pattern still in the process of evolving and then in trying to recognize similar former shapes that had often been altered, truncated or partially hidden by silt.

The sand bars were thus classified in three types (fig.4) :

#### i. Type C1

Triangular-shaped complexes linked on either side of a medium axis formed by a bed of the Rhone. Each triangle has a pointed peak aiming towards the S, and with slightly concave bases usually trending NW-SE and SW-NE.

These complexes appear to be made up of a network of lines (sand bars) that diverge toward the river axis. The triangular complexes are located at the site of successive well-known river outlets (I Saint Ferréol Rhone, II Pecaï Rhone, II' Dead-Branch Rhone, III Present Large Rhone).

.../...

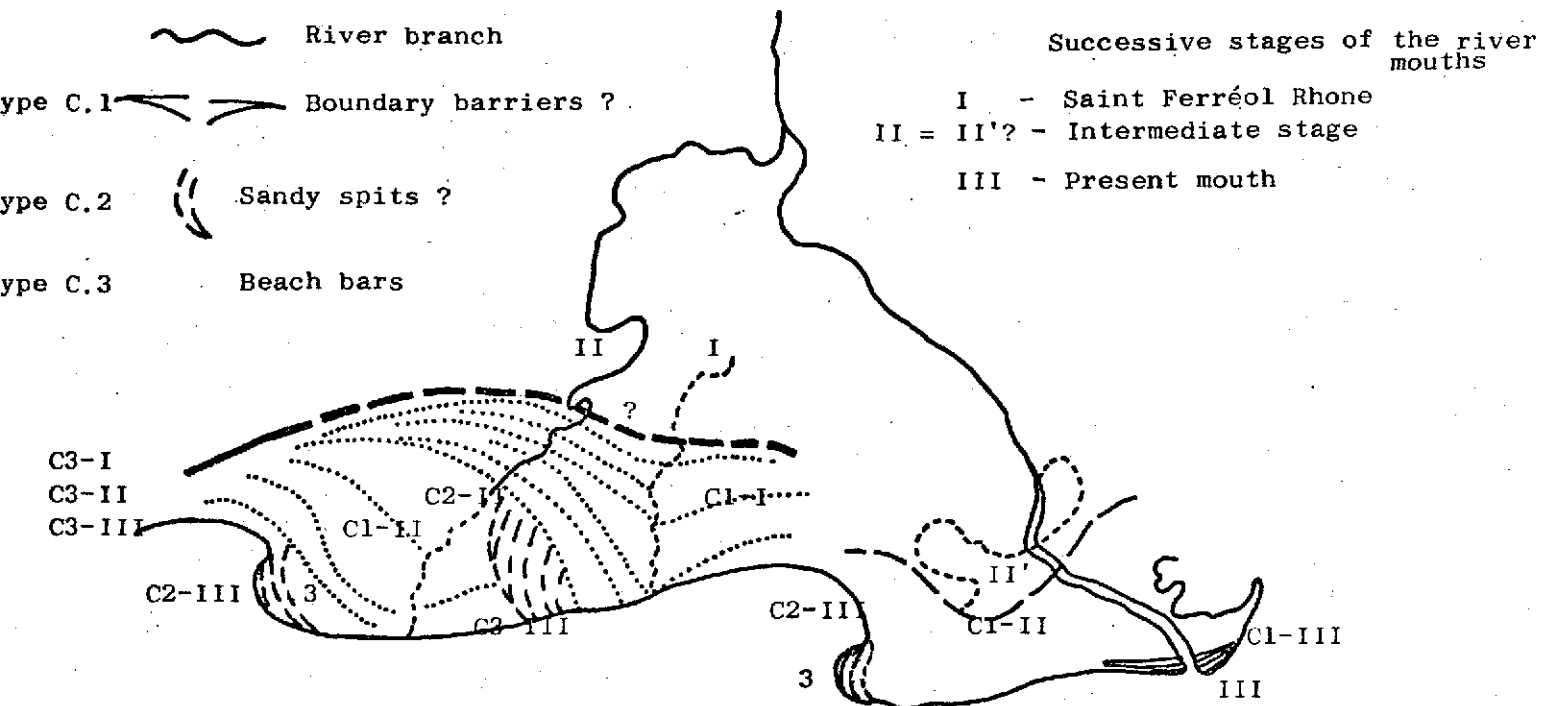


Fig. 3-Sedimentological Hypothesis Based on Satellite Images.

The sign C 1-II indicates a sedimentary shape of type C 1 belonging to stage II.

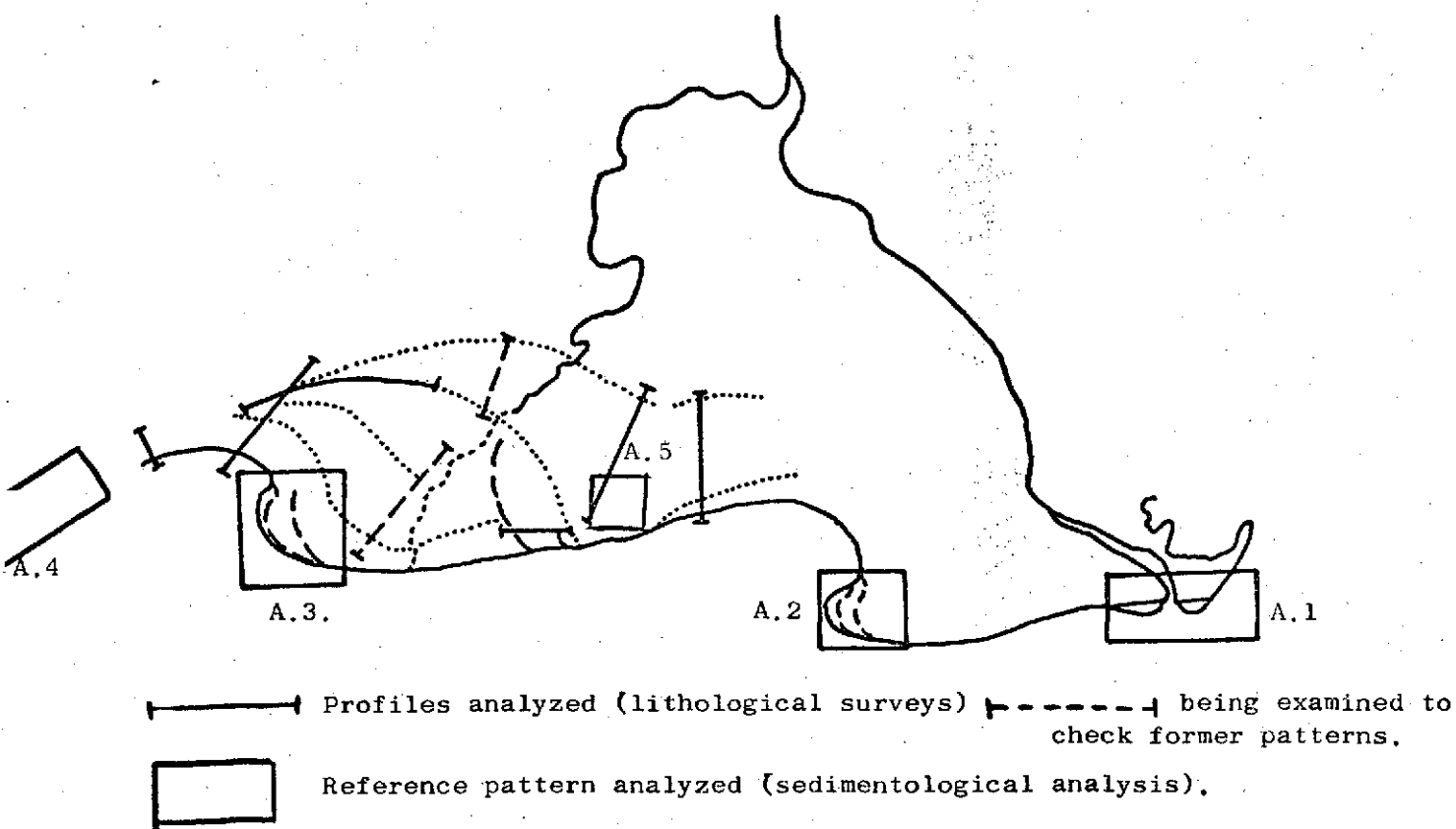


Fig. 4 Scheduled field work.

ii. Type C 2

Curve-shaped nested bars that are convex on the seaward side (W face) to form networks that diverge from S to N (former Clamadour 2 bar, Fig. 3; present Beauduc and Espiguette 3 bars, Fig. 3).

iii. Type C 3

Conventional beach bars generally trending E-W and forming a link between the two preceding types of bars (beaches of Palavas, Saint Maries and the Gulf of Fos).

These morphologies suggest an interpretation for the first type similar to that of the lateral bars created on either side of the river mouth. They have been called "boundary barriers." The second type of bar is similar to the sandy spits created by the reworking and lateral movement of material mainly torn away from the former mouth under the effect of the sea.

### 3.1.3 - Field Checks

To investigate the validity of this hypothesis, a sedimentological field mission was sent out (2). It consisted of the following two phases:

i. Systematic Investigations

Geological mapping surveys on a scale of 1:50,000th from a sedimentological and geomorphological standpoint, and including the mapping of the subsea coastal approaches.

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(2) Carried out in collaboration by BRGM and teams from the Comité

des Techniciens de l'Industrie du Pétrole (CFP, Elf Re, IFP, SNPA).

## ii. Specific Investigations (Fig. 4)

Detailed sedimentary surveys of the present coastal pattern at the same time as of former shapes that had been more or less truncated or altered as the result of coastal or fluvial erosion and of having been filled in by mud from the ponds.

The present reference patterns being analyzed are as follows: the present mouth of the Large Rhone (A 1) which represents the so-called "boundary barrier" model; the points of Beauduc (A 2) and Espiguette (A 3) providing data of the "spits" type; the Palavas beach bar (A 4) and the meander of the Little Rhone (A 5) for understanding the meander bars ("point bar").

The projects undertaken include a topographic survey, a petrographic and granulometric analysis of surface sediments, an ecological inventory of each landscape element, and a definition of the sediment arrangement pattern (sedimentary structures, lithological sequences) determined by means of core samples 8 cm in diameter taken from a depth of one or two meters.

On the former pattern, a series of profiles was chosen after the photos had been examined (cf. Fig. 4). Similar investigations have been begun on former shapes so as to compare them with the results obtained on the present pattern.

The findings made by field observations and the initial analytical results confirm the identifications worked out on the basis of analyzing ERTS images.

### 3.1.4- Interpretation Tests for Evaluating the Holocene Delta

According to this interpretation hypothesis for sand bars, as partially confirmed by field checks, an interpretive theory can be worked out for the recent history of the Rhone Delta.

### 3.1.5 Conclusions - Subsequent Projects

Various profiles were retained (cf. Fig. 4) and will be subjected to a sedimentological analysis of the same type, during the next campaign, so as to confirm the sedimentary nature of the former bars.

However, a historical interpretation can be confirmed only after the complete job of 1:50,000th geological mapping now being done by BRGM and the allied teams (4) and (5) has been completed. The reconstruction of the final stages of the evolution of the Rhone Delta as well as the dating of various events are the only ways of recreating the recent geological history of this region.

However, the revealing of an intermediate phase, as done by this survey, combines such factors as an observation of the ERTS mission photos, sedimentological field checks and reference to a fundamental theory. All this provides us with a precious guide in examining the Rhone Delta.

- 
- (4) Marine geology and applied sedimentology laboratory at Marseilles Lumigny, and pedological research.
  - (5) Mapping must result in a 1:250,000th map that can be directly compared with the enlargement.

The interpretation of the photos tends to prove the existence of three successive morphological structures of the Rhone Delta. Two extreme phases can clearly be seen. On the one hand, in an initial phase there was a vast triangular delta corresponding to the so-called Saint-Ferréol Rhone bed. On the other hand, the present image of an elongated delta has the Large Rhone as the main access. Intermediate stages appear to have existed between these two extreme phases.

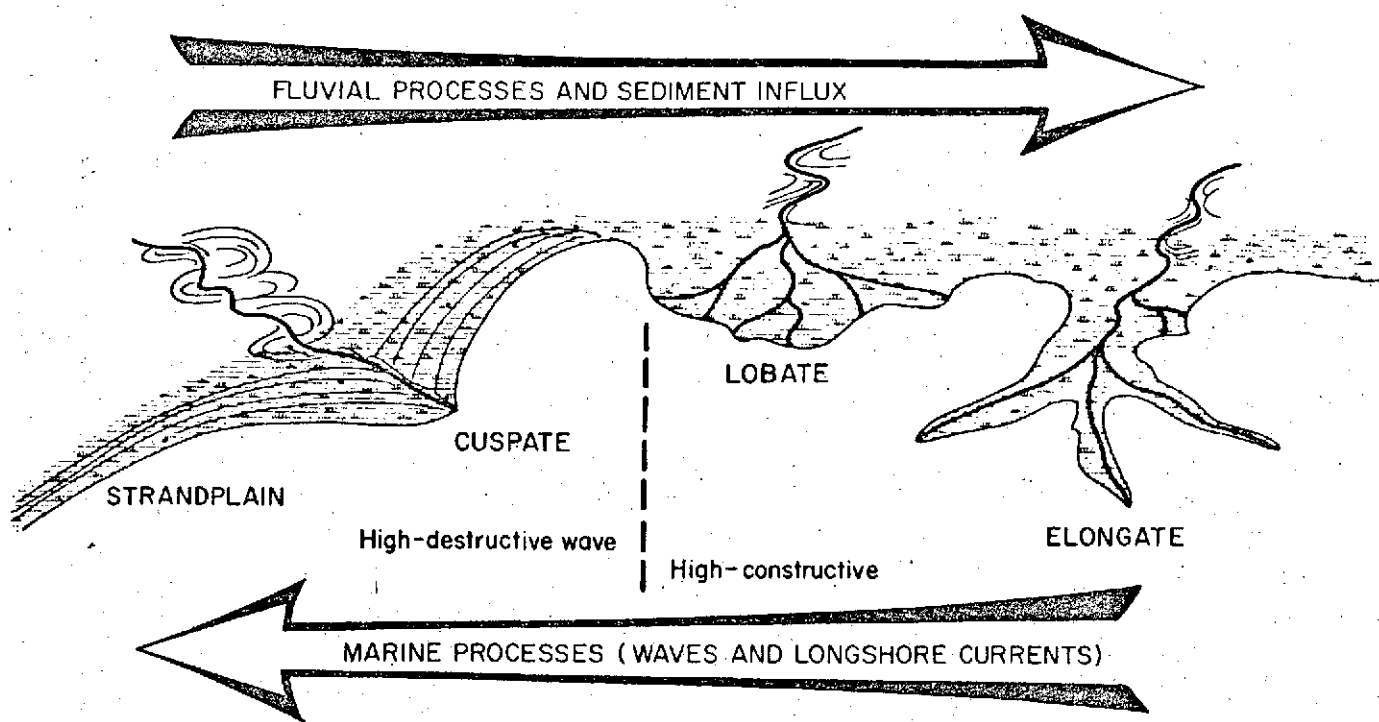
It is interesting to compare the hypothesis described above with A.J. Scott's deductions concerning the evolution of deltas as a function of dominating hydrodynamic effects (Fig. 5). According to this theory, a lobed delta stage occurs between the "elongated" phase and the triangular-morphology phase.

The image of such an intermediate stage was sought for on the photos of the Camargue Plain. The lines of such a morphology are relatively fuzzy (3). Nonetheless, a probable image can be outlined using both the data provided by this investigation and a typical theoretical morphology. Image "b" in Figure 4 may be drawn as a hypothetical working example. It corresponds to an erosion phase of the tip of the Saint-Ferréol Rhone deltaic triangle and the westward transfer of materials to create a system of fossil spits (two in Fig. 6).

---

(3) This confusion appears to stem from two main facts:

- i. For reasons of simplification, a specific phase has deliberately been set apart even though the evolutive process is continuous and results in the obliteration of successive lines by one another.
- ii. The "lobed delta" phase is one of the stages in which the river pattern is especially complex, fingered (cf. the Nile) and morphologically not very typical.



Arrows point in direction of increasing influence

Fig. 5. Relationship of marine processes and fluvial influence on wave-dominated deltaic coastlines. By A. J. Scott.



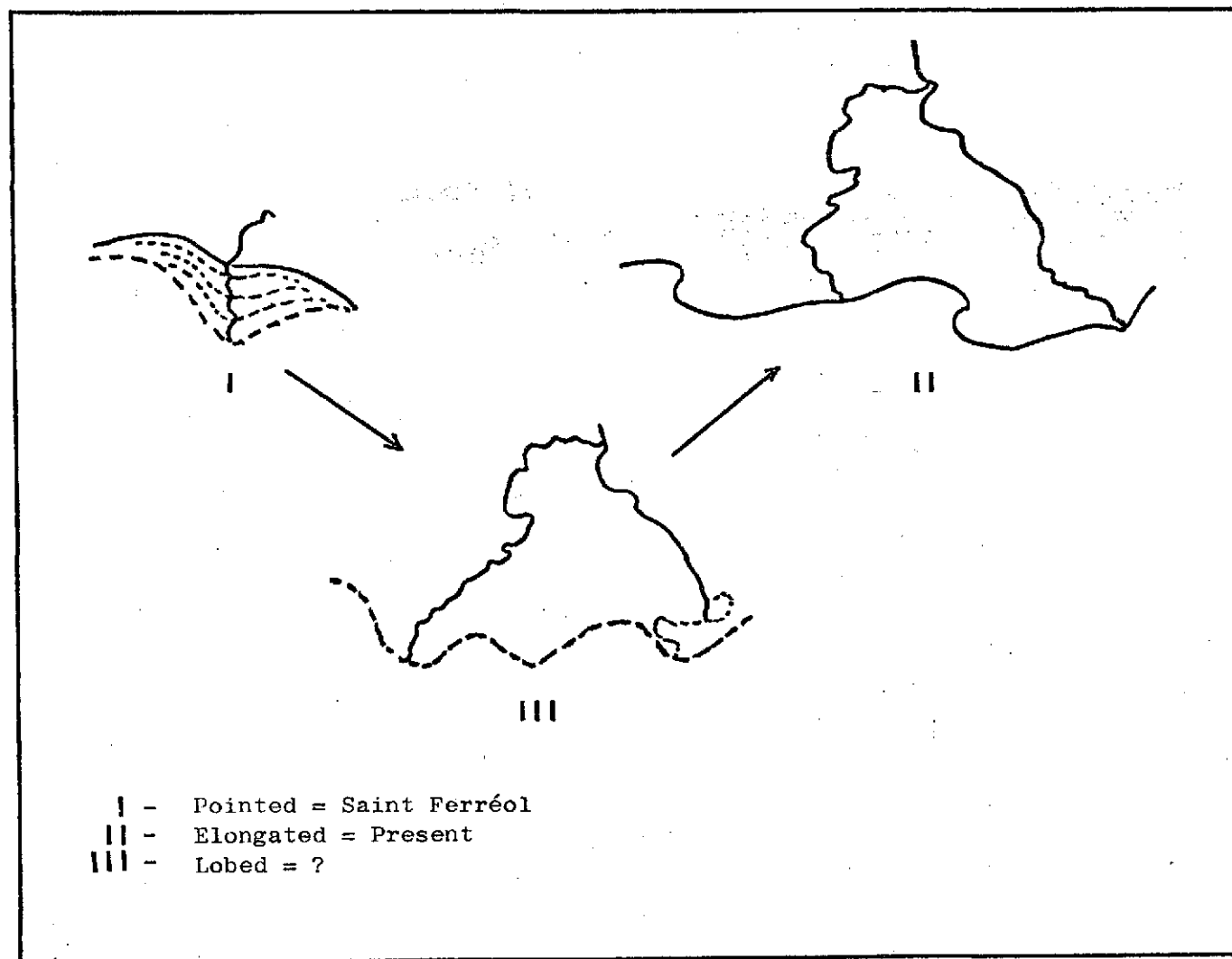


Fig. 6 - Interpretation diagram of how the Rhone Delta evolved according to three successive phases.

### 3.2 - PHOTOGRAPHIC AND THERMOGRAPHIC DATA ON PRESENT SEDIMENTATION PROCESSES

#### 3.2.1 - Quality of Images, Repetition

The fact that the ERTS 1 satellite images have to be repeated every 18 days led us to hope that it would be possible to analyze the mechanism of sedimentation in the Gulf of Lions and on the shore of the Camargue region. It was possible that the Rhone water might be visible on account of its cloudyness or else because it had a different color from that of the seawater.

Repetition of the images should have enabled us to see how the water behaves under different meteorological conditions and perhaps to analyze the phenomenon in a more general fashion with field methods on the grounds.

Seven images were obtained, sometimes of the western part of the Gulf and a small part of the delta, and sometimes of the delta and the Provence coast (Fig. 1 and Table 1).

Cloud frequency partially covers the image, and we had a great deal of trouble at first in distinguishing zones with different water shades.

In reality, only diffuse haze or very small dispersed clouds are truly bothersome for interpretation.

Figure 7, show how the shadows cast by clouds having sufficient opaqueness and size can be used to define the sea surface and to suggest that the nuances found there are caused by its color.

Figure 8, on the contrary, in the form of a print made so as to bring out the smallest nuances of uniform dark gray present on a normal print in band 5,

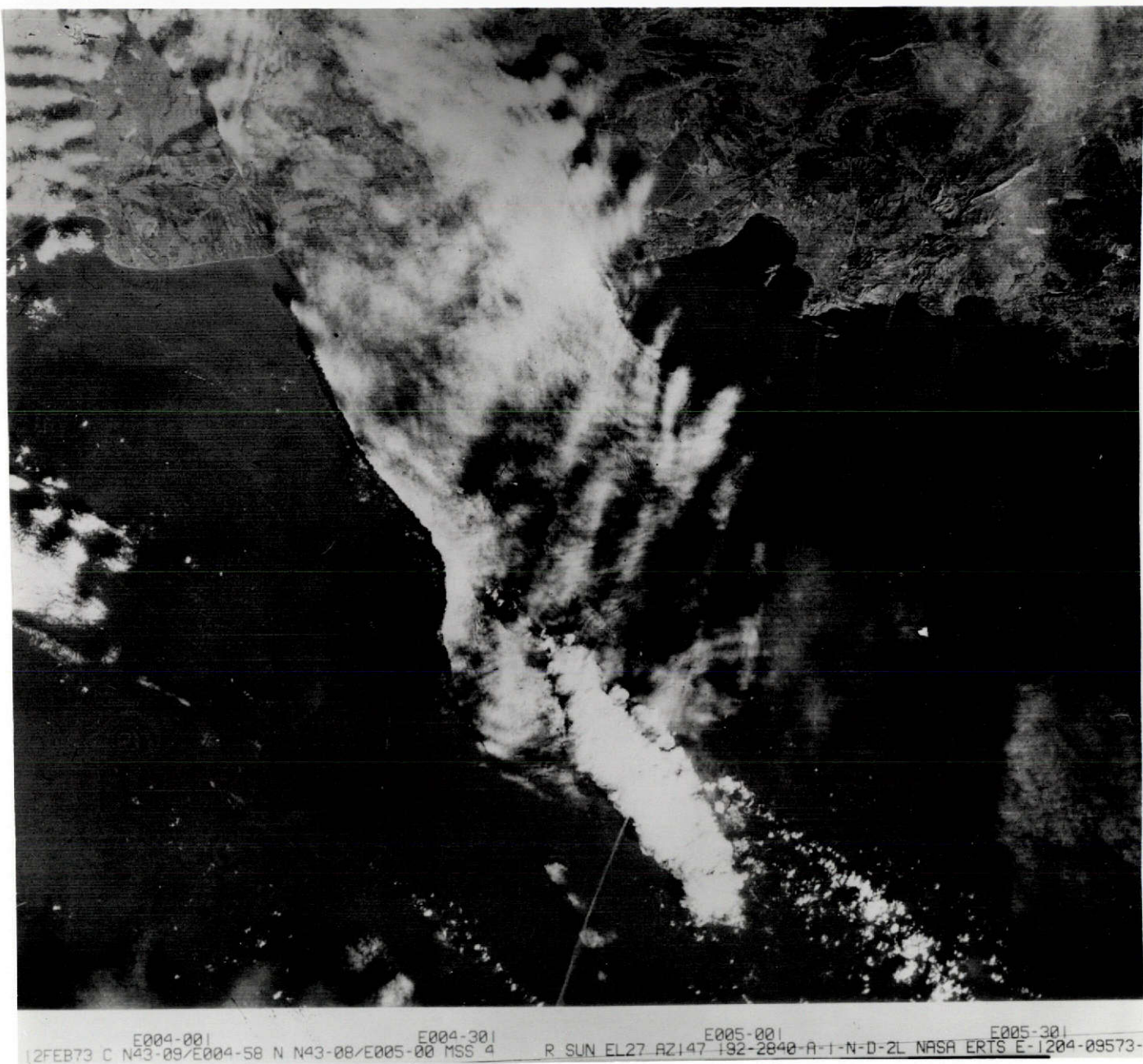


Fig. 7 Shadows cast by clouds can be used to distinguish changes in hue of the image that are due to the water surface color from those due to the presence of haze.



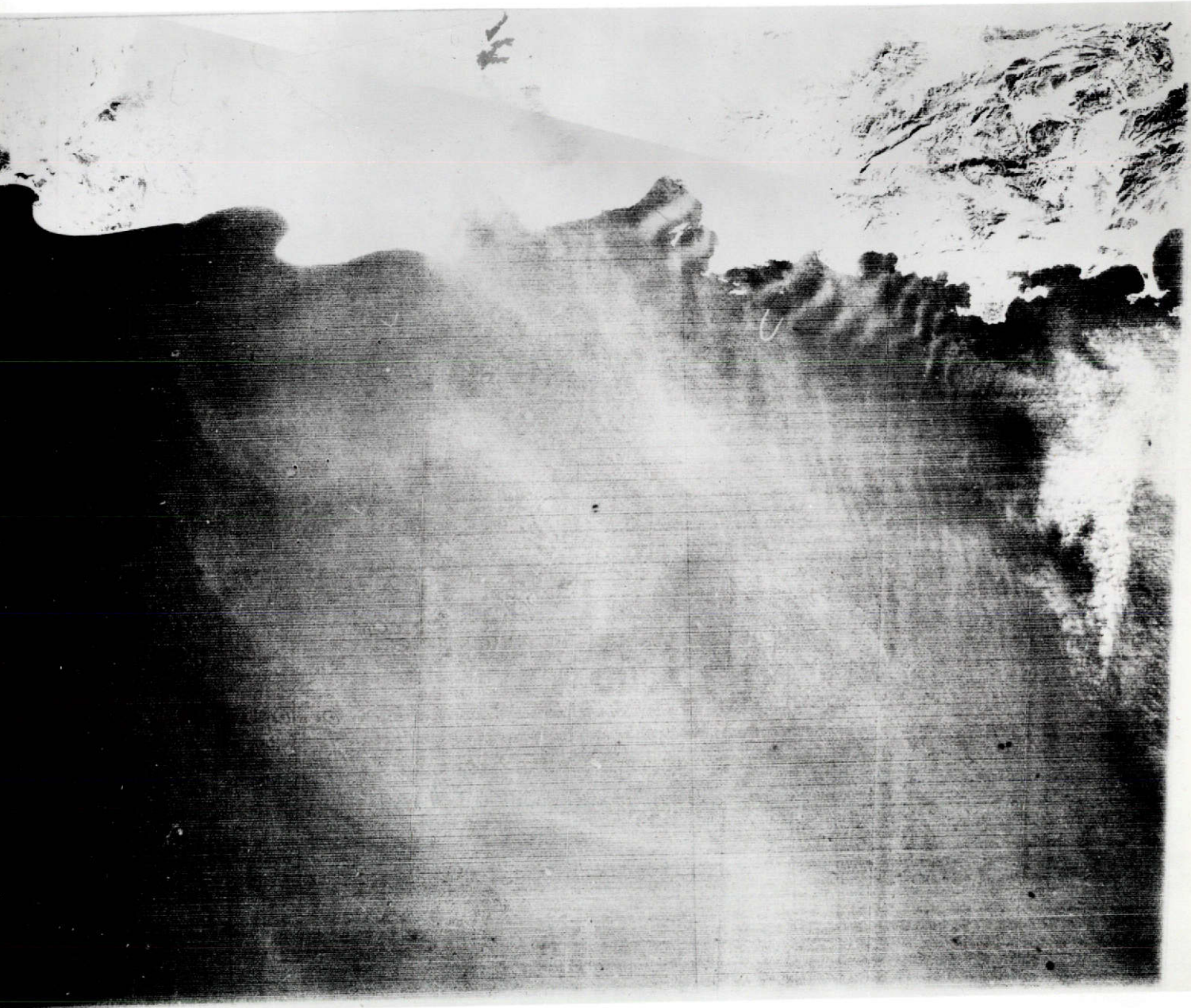
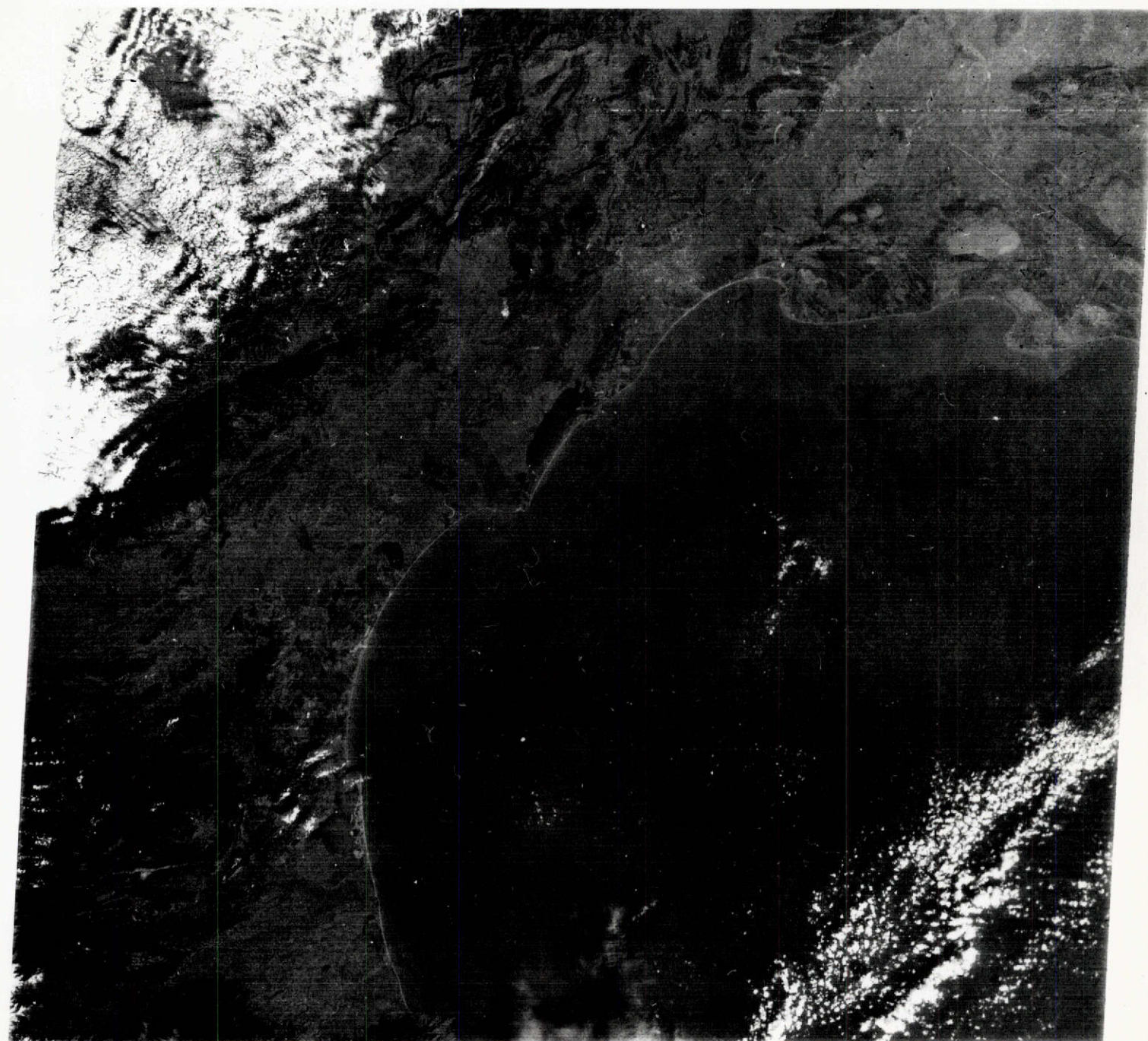


Fig. 8 A special print reinforcing the photographic contrast on the sea to the detriment of the image of the dry land parts, thus showing that some nuances are due to haze and not to water color. In such a case, when the haze casts no shadow on the sea surface, it is difficult to avoid confusion if great care is not taken.





26JAN73 C N43-15/E003-37 N N43-13/E003-40 MSS 4 R SUN EL22 AZ150 192-2603-A-1-N-D-2L NASA ERTS E-1 187-10025-4 02

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Fig. 9 - Mission 4 image of 26 January 1973 in the Gulf of Lions.  
A clear strip can be seen that is cast by cloud shadow  
in the S, thus making certain the attribution of water color.  
It is 10 to 12 km wide and runs parallel to the coast, and  
forms protuberances in an offshore direction (cf. Fig.11).

reveals the periodic structures of haze or light clouds on the right-hand side. The left-hand side observed independently, however, shows shapes that might have been confused with the nuances in the surface-water color.

The images taken on 22 September and especially on 9 October, 12 February and 21 March may give rise to such confusions. On the images taken on 20 December and 12 February, an extensive cloud coverage hides the mouth of the Large Rhone and the Gulf of Fos. Solely the images of 26 January and 21 March give an overall view of the unobstructed gulf.

On the whole, image repetition is thus not very consistent. We found from experience that to be sure of being able to make a dynamic survey, a daily repetition similar to that provided by meteorological satellites would have to be provided.

### 3.2.2.-Observations and Correlations with the Meteorological Circumstances

Image of 26 January 1973 (Fig. 9).

This image is the only one in which a relatively well defined shape appears, enabling this shape to be connected for certain with a coastal phenomenon.

A lighter-colored strip runs quite clearly along the coast over a width of about 10 km. It is especially clear in the E where it gives the impression of "beginning" in a point before spreading out and becoming very fuzzy in the S of the Gulf to the extent where it is not clear where it breaks off.

The edge of this light strip forms two large concavities and appears to have extensions running offshore.

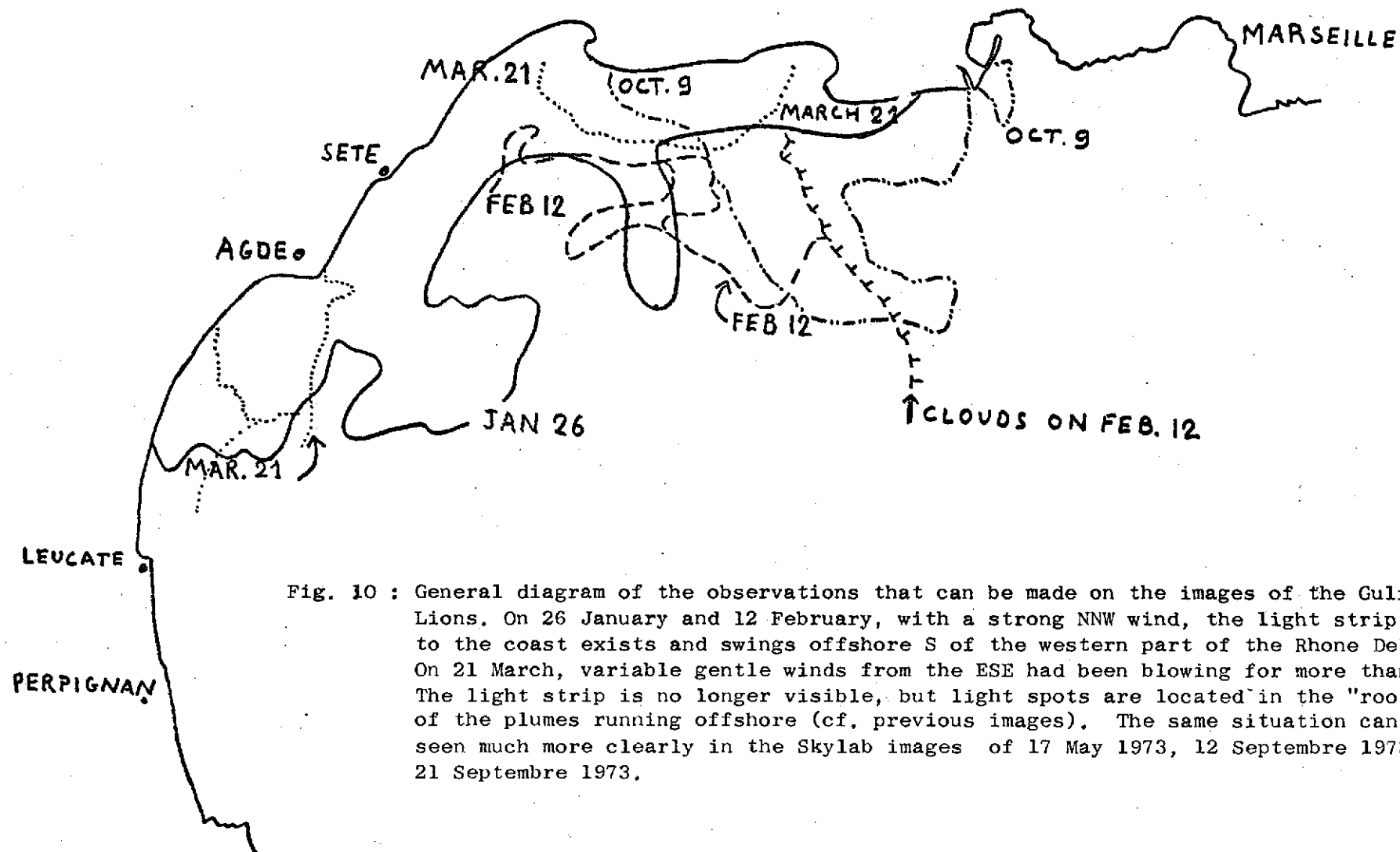


Fig. 10 : General diagram of the observations that can be made on the images of the Gulf of Lions. On 26 January and 12 February, with a strong NNW wind, the light strip parallel to the coast exists and swings offshore S of the western part of the Rhone Delta. On 21 March, variable gentle winds from the ESE had been blowing for more than 6 days. The light strip is no longer visible, but light spots are located in the "root" zones of the plumes running offshore (cf. previous images). The same situation can be seen much more clearly in the Skylab images of 17 May 1973, 12 Septembre 1973 and 21 Septembre 1973.

The diagram (Fig. 10) sums up this observation as well as the similar but highly partial one that can be made on the images of 21 March.

On 9 October and 12 February, less clearcut and quite different shapes appear. But we do not dare interpret them.

In the beginning of our investigation we assumed that this light-colored strip could be attributed to the turbid waters of the Rhone swept back toward the coast by a coastwise current.

However a comparison with meteorological data (Table 3) does not allow this hypothesis to stand up. Indeed, on the dates when the light strip is visible along the coast (26 January, 12 February, and 21 September 1973), the dominating wind on the preceding day was from the NNW, generally with fairly good velocity. On the contrary, with an E wind that should push the flow from the Rhone back toward the coast, this light strip is not visible.

The Skylab color photos which provide much more information than the ERTS 1 band images, clearly confirm this impression. The light strip parallel to the coast of the Gulf occurs with a strong wind from the NNW and does not appear for a "sea" wind from the E or SE.

Perhaps this light strip can be linked to the accumulation of sand and dust carried from onshore toward offshore by the wind? Investigations of this hypothesis are now being made.



On the 26 January 1973 image as well as on the 21 September 1973 Skylab photo, we also found that these light strips, in addition to running parallel to the coast, outlined protuberances running offshore. This suggested return currents running offshore (rip currents) entraining surface water that had become yellow.

A thermographic mission\* carried out on 26 June 1973 on a very small scale (1/100,000th) showed that this hypothesis was quite probable (Fig. 11).

Indeed, S of Agde, the plumes from the coastal rivers are entrained toward the NE. East of Agde, on the contrary, entrainment runs towards the SW. The Hérault, which empties into the sea right at the foot of Cap d'Agde, is abruptly pushed eastward by the coastal current and then southeastward in an offshore direction when it meets the assumed "return current" (Fig. 11).

Obviously, the coinciding similarity of the thermographic and satellite images might be accidental. Therefore, more thorough investigations were undertaken. They will use the thermal images from the NOAA 2 and 3 satellites as well as additional airborne thermographic experiments.

#### 4 - CONCLUSION

This survey has shown that satellite images may be of considerable help in guiding a survey of recent sedimentation in a delta, by providing an overall interpretation pattern.

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\* Mission carried out by IGN for the Centre National d'Etudes Spatiales (Langrou Mission).

Whereas the meteorological circumstances did not enable as much advantage as had been hoped to be taken of the image repetition, the coinciding of these images with specific meteorological circumstances enabled hypotheses to be put forward. At the same time, the combined use of airborne thermography was also tested. Likewise, it was found that it was almost impossible in practice to synchronize airplane flights with satellite passages.

However, it can be suggested that if a denser repetitivity (e.g. every two or five days) could be used to overcome poor meteorological conditions, a much more thoroughgoing organization would be required in order to be able to make use of such coverage.

In this sense, the experiments have entirely fulfilled their purpose which was to try out a new operating method. Material difficulties appeared and seriously compromised or at least considerably delayed the project. However, the results are promising, and new approaches were found.

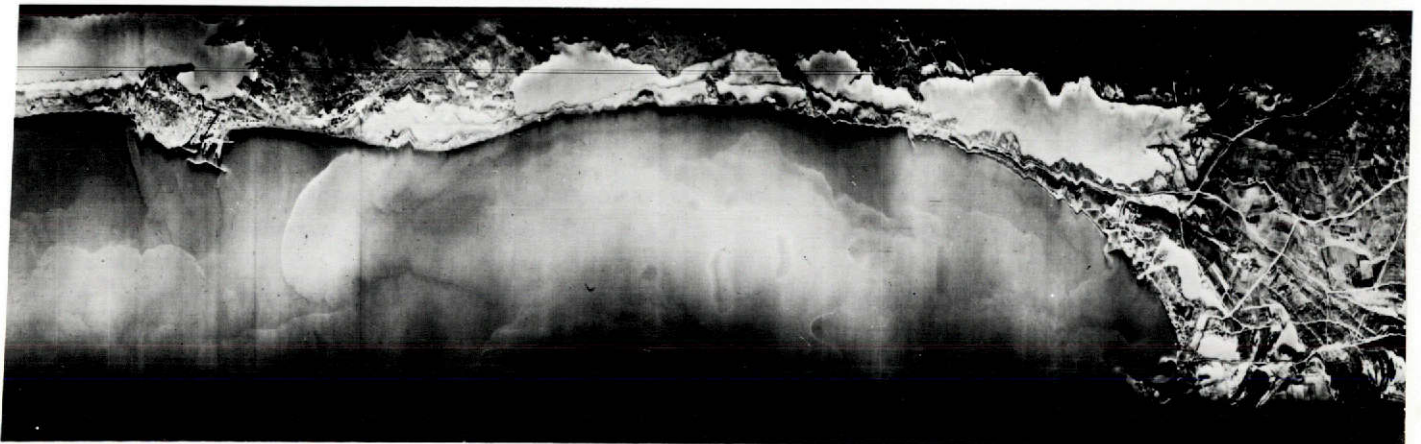
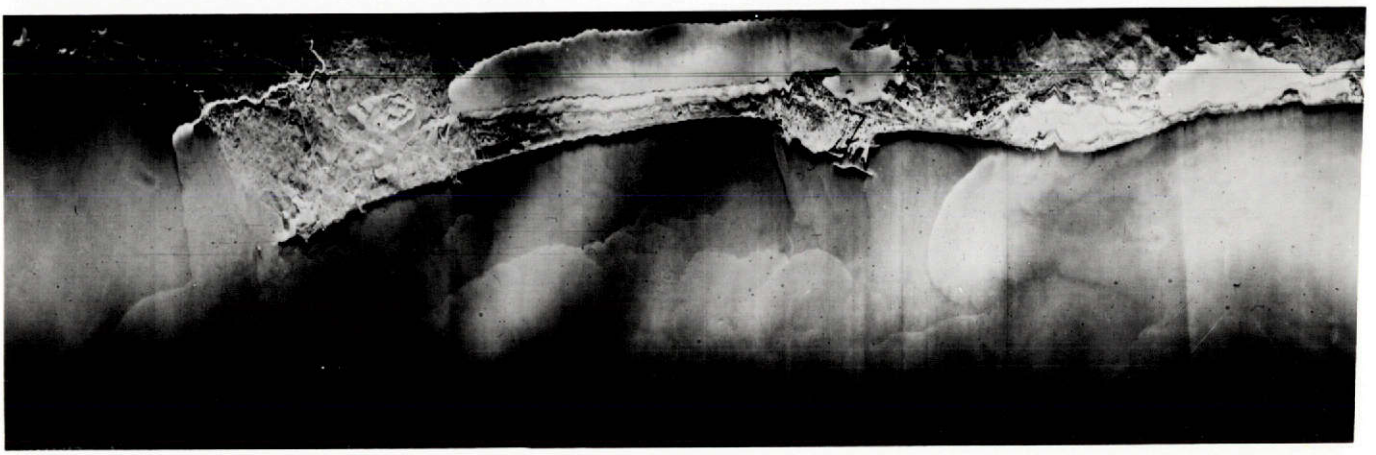
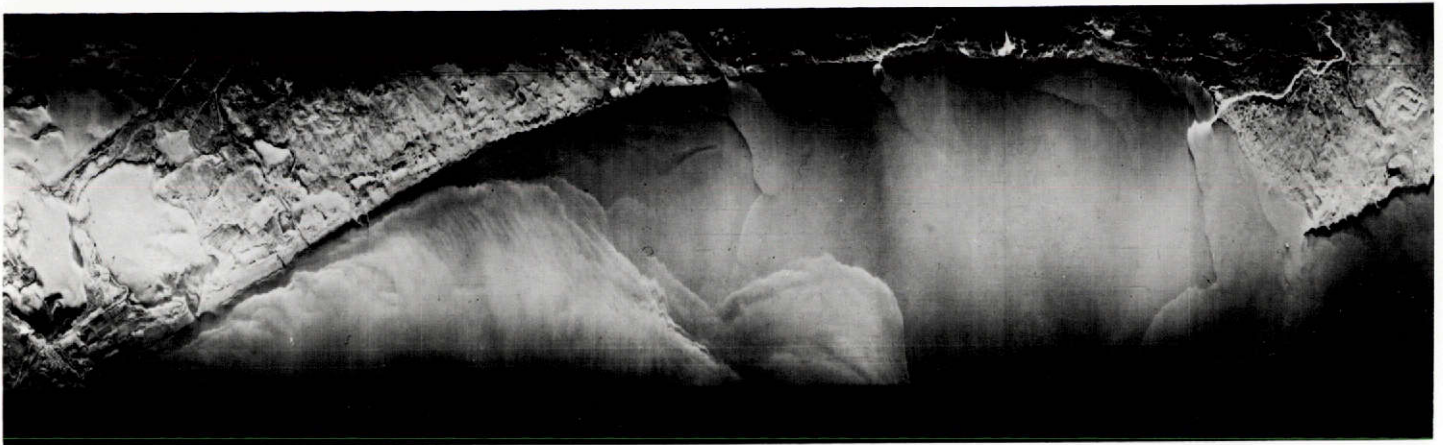


Fig. 11

Legend of fig.11

Three small-scale thermographs (about 1:200,000 th) of the coast of the Gulf of Lions may be compared with the satellite images (CNES-Langrou mission, 26 June 1973).

Both a bands show, when set end to end, the shoreline of the Gulf from the Port of La Nouvelle (upper left) to Agde, then from the latter town to Port Camargue (lower right). This coverage took place between midnight and 1 AM during a rising tide (seawater is penetrating into the ponds). Band B shows the portion of the shoreline between Sète and the Camargue region three hours earlier at low tide (the ponds are emptying into the sea).

In the upper image, a mass of warmer water is moving from SW toward NE. The second river from the left is also pushed back toward the NE, whereas the third river just before Cap d'Agde is sharply pushed back along the shore of the cape and then drawn offshore, after which it forms a lobe in the SSW as if it had encountered a current running along the other shore of the cape. The middle image appears to show, E of Sète, a mass of water moving toward the WSW, whereas the outlets of the ports of la Grand Motte and Port Camargue are pushed toward the SSE.

At low tide, the outflow the ponds to the sea gives a much clearer indication of the current moving SW.

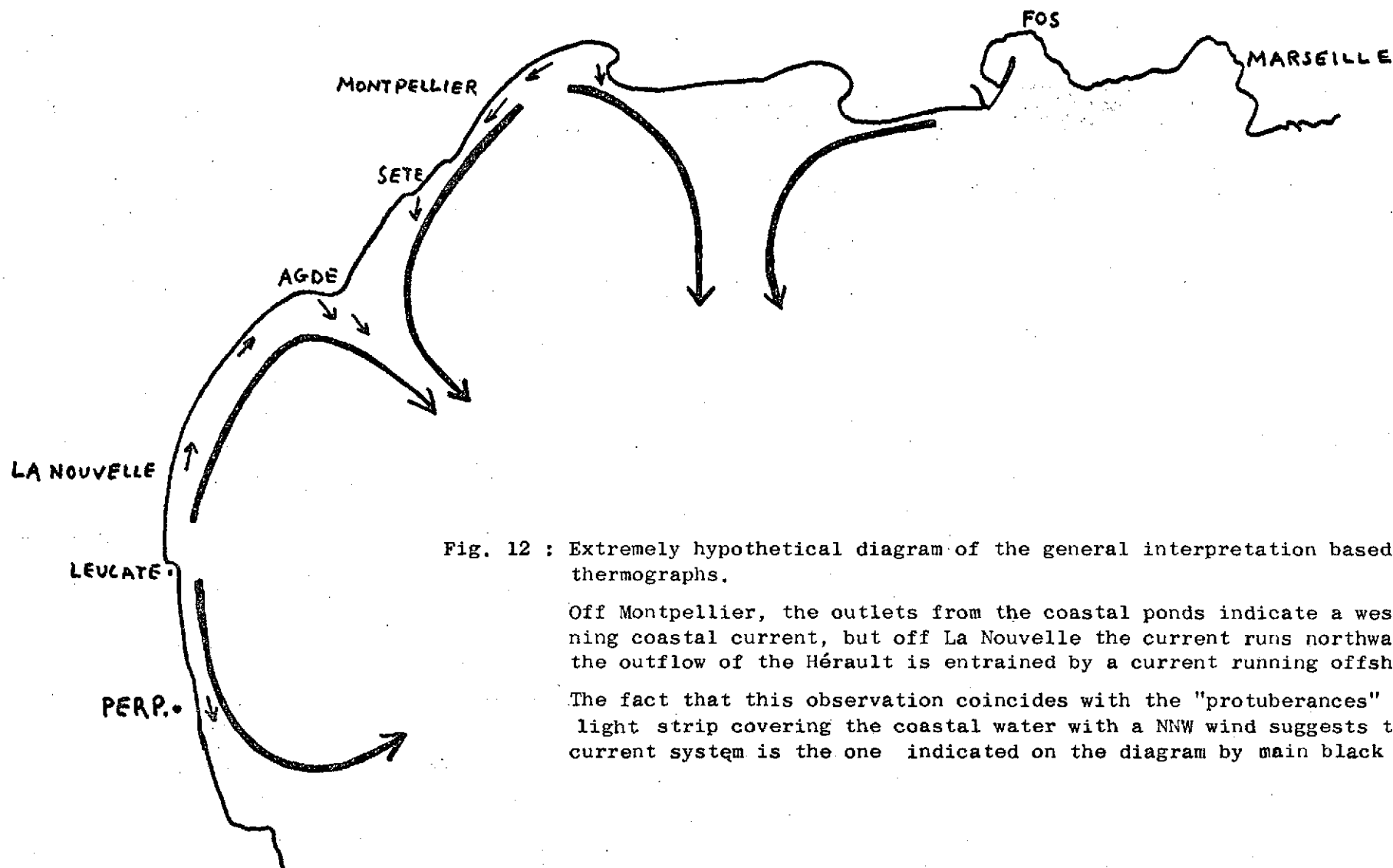


Fig. 12 : Extremely hypothetical diagram of the general interpretation based on thermographs.

Off Montpellier, the outlets from the coastal ponds indicate a westward-running coastal current, but off La Nouvelle the current runs northward, whereas the outflow of the Hérault is entrained by a current running offshore.

The fact that this observation coincides with the "protuberances" in the light strip covering the coastal water with a NNW wind suggests that the current system is the one indicated on the diagram by main black arrows.

.../...

5 - LIST OF PUBLISHED PAPERS AND REPORTS

- Jean Pierre BERTRAND, Max GUY, Alain L'HOMMER

Complexity of recent and present sedimentation in the Rhone delta and along the french mediterranean coast - (GOLION project).

Symposium on European Earth Resources Satellite experiments, 28 Jan, 1 FEB 1974, FRASCATI (ITALY).

- Guy CABALLE, Bernard LACAZE, Gilbert LONG, Geneviève RIMBAULT.

Etude qualitative de quelques images ERTS 1 du projet GOLION - Aspects écologiques des milieux terrestres.

Symposium on European Earth Resources Satellite experiments, 28 JAN, 1 FEB, 1974, FRASCATI, ITALY.

- Guy CABALLE, G. LONG

Contribution à l'étude des images ERTS 1 à l'échelle du 1/1.000.000 du projet GOLION (LANGUEDOC-ROUSSILLON).

C N R S - C E P E - MONTPELLIER - SEPT.1973

- A. FONTANEL, J. GUILLEMOT, M. GUY

First ERTS 1 results in southeastern France : geology, sedimentology, pollution at sea.

Symposium on significant results obtained from ERTS 1, March 5-9; 1973- Vol. 1, paper R6, p.1483-1511.

- Max GUY

La complexite de la sedimentation holocène dans le delta du Rhone - Revue "PHOTO INTERPRETATION" 1973 - 1 p. 35-48

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1058-09450M	X	X		BAY, CAPE, ISLAND RIVER, ESTUARY DENDRITIC DRAINAGE,
1058-09450 4	X	X		HAZE, RUNOFF,
1058-09450 5	X	X		<del>HAZE</del> RUNOFF, URBAN AREA, VEGETATION, AIR FIELD
1060-09554 M	X	X		

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1060-09561 M	X		X	SNOW, VALLEY,
1060-09561 4				HAZE, AGRICULTURE, VEGETATION
1060-09561 5				AGRICULTURE, VEGETA TION, HIGHWAY,
1060-09561 6				RIVER, CANAL, HIGHWAY GEOLOGY,
1060-09561 7				RIVER, CANAL, URBAN AREA, GEOLOGY
1061-10015 M	X		X	VALLEY,
1061-10015 4				HAZE, CANAL, VEGETATION,
1061-10015 5				VEGETATION, AGRI- -CULTURE, HIGHWAY
1061-10015 6				RIVER, CANAL, DENDRITIC DRAINAGE, PARALLEL DRAINAGE, FAULT, GEOLOGY LAKE,
1061-10015 7				

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	CLOUDS	COAST		
1061-10022-M	X	X		DELTA, LAKE, COASTAL PLAIN, HARBOR, RIVER
1061-10022-4				HAZ E
1061-10022-5				AGRICULTURE
1061-10022-6) 7}				RETROGRESSIVE SHORE -LINE, ADVANCING SHORELINE (FORMERLY)
				BARRIER BEACH, BARRIER LAKE

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1076-09442-M				SNOW, VALLEY LAKE, MOUNTAIN PIEDMONT PLAIN, ALLUVIAL PLAIN, FAULT
1076-09442-5				AGRICULTURE GLACIER
1076-09442-6				RIVER, URBAN AREA, HIGHWAY
1076-09442-7				RIVER, URBAN AREA

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1078-09564-4	✓		✓	AGRICULTURE, RUNOFF
1078-09564-5	✓	✓	✓	AGRICULTURE, RUNOFF
1078-09564-6	✓		✓	ADVANCING AND RETRO- GRESSIVE SHORELINES, URBAN AREA
1078-09564-7	✓		✓	ADVANCING AND RETRO- GRESSIVE SHORELINES, URBAN AREA

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1149-09511-M	✓		✓	SNOW, MOUNTAIN, PIEDMONT PLAIN, COAST LINE, DENDRITIC DRAINAGE, CLOUD, RIVER
1149-09511-4	✓	✓	✓	HAZE
1149-09511-5	✓	✓	✓	
1149-09511-6	✓		✓	URBAN AREA
1149-09511-7	✓		✓	URBAN AREA

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1167 - 09512 - M	✓		✓	SNOW, CLOUD, RIVER, COAST LINE, ISLAND, BAY, CAPE, ESTUARY, DENDRITIC DRAINAGE
1167 - 09512 - 4	✓	✓	✓	RUNOFF
1167 - 09512 - 5	✓	✓	✓	RUNOFF
1167 - 09512 - 6	✓		✓	
1167 - 09512 - 7				

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1187-10023-M	✓			RIVER, SNOW, VALLEY, CANAL
1187-10023-4	✓	✓		
1187-10023-5	✓	✓	✓	AGRICULTURE, HIGHWAY
1187-10023-6	✓		✓	HIGHWAY, URBAN AREA MOUNTAIN
1187-10023-7	✓		✓	URBAN AREA, MOUNTAIN

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1187-10032-4				
1187-10032-5		✓		
1187-10032-6	✓		✓	COAST LINE, MOUNTAIN
1187-10032-7	✓		✓	COAST LINE, MOUNTAIN

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	GEOLOGY	VEGETATION	FAULT	
<del>1204</del> 1204-09573-M	✓		✓	CLOUDS, COAST, BAY, RIVER, DELTA, HARBOR ISLAND, CAPE
1204-09573-4	✓	✓	✓	AGRICULTURE
1204-09573-5	✓	✓	✓	AGRICULTURE
1204-09573-6	✓		✓	ADVANCING AND RETRO- GRESSIVE SHORELINES, URBAN AREA
1204-09573-7	✓		✓	ADVANCING AND RETRO- GRESSIVE SHORELINES, URBAN AREA

\*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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NASA GSFC  
GREENBELT, MD. 20771  
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# ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

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DATE MAY 3<sup>rd</sup> 73

PRINCIPAL INVESTIGATOR Max GUY

GSFC 009-1

ORGANIZATION INSTITUT FRANÇAIS DU PETROLE

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N \_\_\_\_\_

ID \_\_\_\_\_

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	GEOLOGY	VEGETATION	FAULT	
1221-09513-M	✓		✓	SNOW, MOUNTAIN, PIEDMONT PLAIN, COAST LINE, DENDRITIC DRAINAGE
1221-09513-4	✓	✓	✓	
1221-09513-5	✓	✓	✓	
1221-09513-6	✓		✓	RIVER, URBAN AREA
1221-09513-7	✓		✓	RIVER, URBAN AREA

\*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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# ERTS IMAGE DESCRIPTOR FORM

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DATE MAY 3<sup>rd</sup> 73

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N \_\_\_\_\_

ID \_\_\_\_\_

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	GEOLOGY	VEGETATION	FAULT	
1221 - 09515 - M	✓		✓	SNOW, CLOUD, RIVER COAST LINE, ISLAND, BAY, CAPE, ESTUARY, DENDRATIC DRAINAGE
1221 - 09515 - 4	✓	✓	✓	RUNOFF
1221 - 09515 - 5	✓	✓	✓	RUNOFF
1221 - 09515 - 6	✓		✓	URBAN AREA
1221 - 09515 - 7	✓		✓	URBAN AREA

\*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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N \_\_\_\_\_  
ID \_\_\_\_\_

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	GEOLOGY	VEGETATION	FAULT	
1222 - 09571 - M				CLOUD, SNOW, MOUNTAIN DENDRITIC DRAINAGE
1222 - 09571 - 4		✓		
1222 - 09571 - 5	✓	✓	✓	
1222 - 09571 - 6	✓		✓	
1222 - 09571 - 7	✓		✓	

\*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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